Community Development Patterns and
Energy Conservation Study

Technical Appendix

Ministry of
Municipal Affairs
and Housing
Ontario

COMMUNITY DEVELOPMENT PATTERNS AND ENERGY CONSERVATION STUDY

TECHNICAL APPENDIX

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Woods Gordon
Management Consultants
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THE STARR GROUP
ENERPLAN CONSULTANTS LTD.
ALLEN-DRERUP-WHITE LTD.
McCORMICK, RANKIN &
ASSOCIATES LTD.

TECHNICAL APPENDIX

QUANTIFICATION OF LAND USE/ ENERGY CONSUMPTION RELATIONSHIPS

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1.0 INTRODUCTION

As an important component of the Community Development Patterns and Energy Conservation Study, a method was developed and applied to quantify basic land use/energy consumption relationships. This method was designed to incorporate a number of fundamental characteristics, including:

- a high degree of flexibility for potential application in communities throughout Ontario.
- a capacity for analysis of broad community land use patterns, rather than the characteristics of specific sites and buildings.
- practical relevance for municipal planning purposes including a capacity for forecasting and spatial representation of land use/energy consumption relationships.
- suitability for application with readily available data, and without the need for specialized energy management resources or expertise.

In view of these requirements, the method was developed by combining the findings from an extensive review of related literature and previous experience in energy analysis with those revealed during development and application of the approaches used in the present study.

The purpose of this Technical Appendix is to outline the principles, concepts and procedures involved in quantifying land use/energy consumption relationships. Application of the method, at a general level for London and Peterborough, is also described. The application, which is intended primarily to provide a demonstration of the workings of the method, produces rough estimates of the magnitude of energy savings which can be achieved through land use planning measures. Ideally, the method is applied directly at the local level where the potential for accuracy and detail is greater.

1.1 INTRODUCTION

As an important component of the Comprehensive Land Use Planning and Energy Conservation Study, a method was developed and applied to quantify land use/energy conservation relationships. This method was designed to incorporate a number of fundamental characteristics, including:

a. a high degree of flexibility for potential application in similar land development projects.

b. a capability for analyzing broad community land use patterns, rather than the characteristics of specific areas and buildings.

c. practical procedures for analyzing alternative planning concepts, providing a capacity for understanding and rapid communication of the land use/energy relationships.

d. suitability for use by planners with commonly available data, and ability to be used for specialized energy management studies if required.

In view of these considerations, the method was developed by combining the findings from an extensive review of relevant literature and previous experience in energy analysis with those generated during development and application of the procedures used in the present study.

The purpose of this technical appendix is to outline the rationale, concepts and procedures involved in quantifying land use/energy conservation relationships. Application of the method, as a general guide for London and Middlesex, is also described. The application, which is intended primarily to provide a demonstration of the workings of the method, produces rough estimates of the magnitude of energy savings which can be achieved through land use planning measures. Ideally, the method is applied directly at the local level where the potential for accuracy and detail is greater.

2.0 METHOD

There are two components to the method used for quantifying land use/energy consumption relationships. The first component is based on the development and application of "energy consumption co-efficients" for specific land uses. The second component is a simple transportation energy estimating procedure. Each component will be described below.

2.1 Energy Consumption Co-efficients

These co-efficients are standards expressing an amount of energy used per a specified unit of measure over a specified time period. To illustrate, 1000 KWH/m^2/yr. represents 1000 Kilowatt hours of energy used annually per square meter of floor area. Consumption can also be expressed "per dwelling unit" "per employee", "per hectare", and so on. Consumption co-efficients, in effect, are standards similar to the standards planners have been using for many years, such as: 2.9 persons per household, $1m^2$ floorspace per capita, or 1.5 parking spaces per dwelling unit.

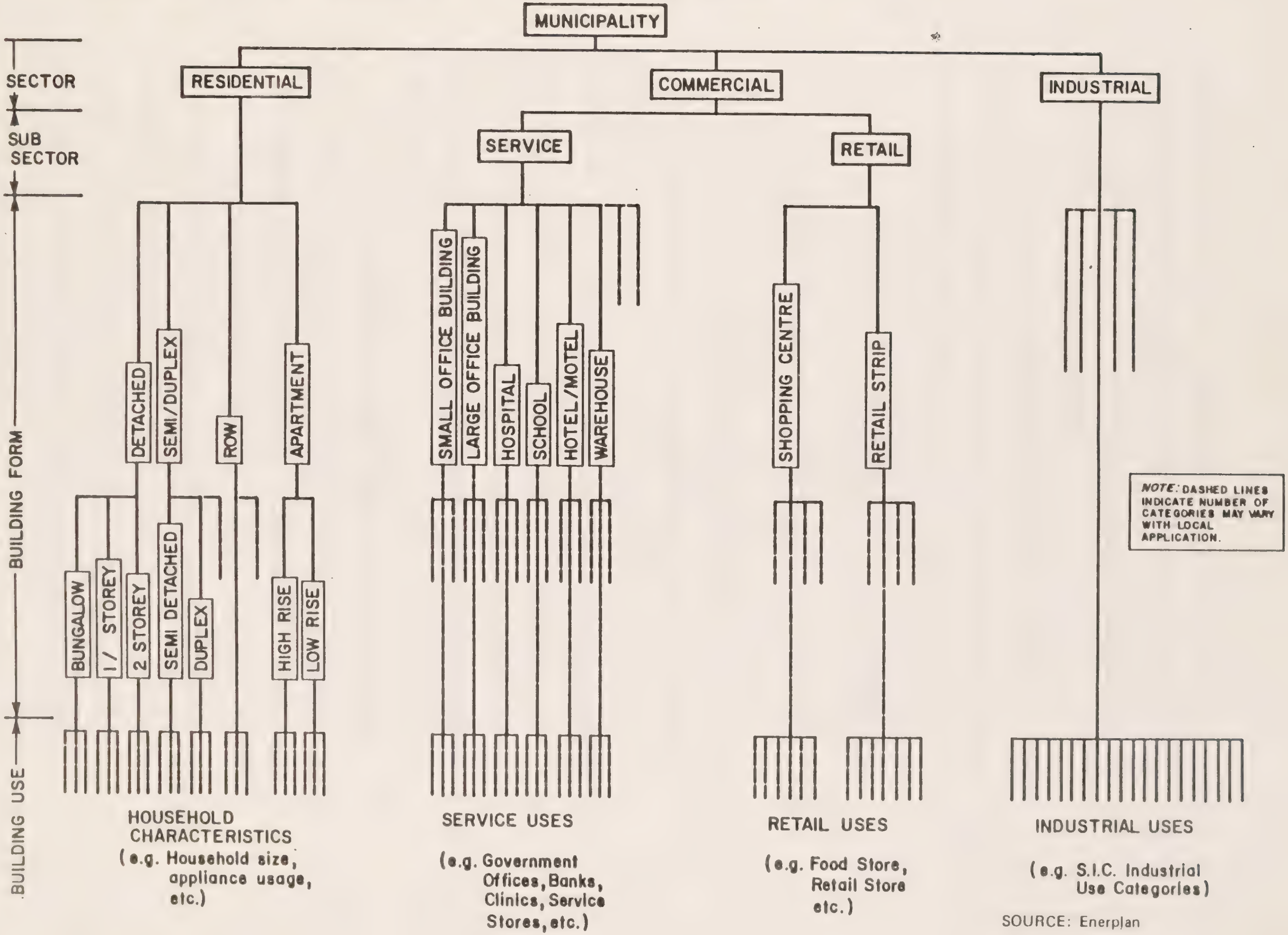
Energy consumption co-efficients enable relationships to be expressed in familiar land use planning terms. They provide a way of integrating energy analysis into ongoing planning activities.

A great deal of confusion exists in the application of energy consumption co-efficients, since there is a tremendous range of land use sectors and sub-sectors, building types and development forms, any of which can be quantified in various units of measurement.

In order to clarify this situation and to establish a general framework for co-efficient application, a land use hierarchy was

FIGURE A-1

HIERARCHY FOR COMMUNITY ENERGY USE ANALYSIS:



SOURCE: Enerplan

constructed (figure A-1). The hierarchy is based on the premise that, within each land use category, energy consumption varies generally with building form and, at a more detailed level, with the various uses that can be carried out within each form.

The central thrust of the method is that, for a given "cell" in the hierarchy, a consumption co-efficient must be matched with data concerning building form or use. The basic formula is:

BASE DATA	ENERGY CONSUMPTION COEFFICIENT	=	ENERGY CONSUMPTION
(e.g. No. of dwelling units)	(e.g. KWH/dwelling unit/year)		(e.g. KWH/year)

For a cell at the level of building form, units which measure floor area (e.g. m^2), building volume (e.g. m^3) or other indicators of physical size are most appropriate. For a cell at the building use level, units measuring "activity" such as employment, industrial production, sales volume, etc. are most useful. The intent in co-efficient application is to achieve increasing levels of detail using base data and consumption co-efficients which are developed at the local level.

The hierarchy is not a fixed, finished framework. As shown in Figure A-1, cells can be added or deleted to reflect the type of development that is being analyzed. Also important is the basic nature of energy consumption in different land use sectors. In the residential sector, for example, consumption relates generally to common categories of building form. Analysis at this level typically leads to realistic results. On the other hand, industrial consumption varies greatly with the specific industrial use, often regardless of the

building in which it is housed; analysis at the use level is therefore most useful. For the complex commercial sector where energy use varies greatly with both building form and use, both levels of analysis can be appropriate.

To summarize, the energy consumption co-efficients method is based on matching co-efficients to base data for various categories and sub-categories of building form and building use within each land use sector. The hierarchy provides a general guideline for defining categories, which can be adapted to suit local requirements. Analysis can be as detailed or as broad in scope as is necessary to meet the specific requirements of local application. Furthermore, using this basic approach, it is possible to estimate energy consumption for any area or any time horizon for which basic planning data are available.

2.2 Transportation Energy Estimates

Two approaches were examined for producing transportation energy estimates. The first is based on total number of automobiles registered in the municipality and an assumed value of total fuel used per vehicle per year. This is the approach used in the energy profile pilot study for the City of Windsor.[1] The approach is simple to use, it can easily be made more accurate by disaggregating automobiles and fuel per vehicle by size of engine and by including urban transit fuel use. In the Windsor study the estimated transportation energy amounted to 23% of the urban energy total. This is very close to the widely quoted proportion of 25% of energy being used by the transportation sector.

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[1] Energy Conservation Through Land Use Planning Pilot Study: Energy Profile, City of Windsor Planning Dept., April 1982.

Unfortunately, this approach leaves untouched the important spatial variables of trip length and of congestion effects on average speed. Both these factors are important in examining land use - transportation energy relationships. In this first approach these factors are subsumed in the assumption of fuel used per car per year. This means that the only source of variation in transportation energy over time is a change in total vehicles or a change in fuel used per vehicle per year. Neither of these effects allows an examination of the effect of a change in urban form on transportation energy.

The second method examined is based on total automobile work trips, average trip length and average speed. This method explicitly takes into account the variables which are related to urban form: trip length and average speed. The major assumption with this method lies in the fuel consumed per kilometre - vehicle speed relationship. This relationship is based on assumptions regarding vehicle operating conditions such as, stop and start traffic and air temperature.(1)

In more detail, the second method operates as follows:

1. Determine total number of automobile work trips. Sources include the Statistics Canada Annual Travel to Work Survey or local transportation study data.

2. Determine average work trip length. Sources are the same as in 1.

3. Calculate total work kilometers travelled as: numbers of trips X average trip length X 2 (for travel to and from work).

4. Determine average vehicle speed. Sources are the same as in 1.

5. Determine fuel used per kilometre travelled for the given average speed.

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1 The effects of changes in average speed will be non-linear as the fuel consumption per kilometre (verticle axis) and average speed (horizontal axis) relationship is U-shaped. The low point on the curve occurs at about 35 km/h.

6. Calculate total fuel used as: kilometres travelled X fuel used per kilometre.

7. Convert litres of fuel to kilowatt hours (KWH) measure.

The second method is limited because it applies only to work trips. Both methods examine only passenger travel and ignore urban freight movement. It is possible to apply an expansion factor to the work trip or total passenger trip energy figure to arrive at an estimate of total urban transportation energy. The expansion factor would be based on the findings of other transportation energy studies. However, in using an expansion factor two problems arise. First, because the factor is based on studies at different geographic scales or based on other urban areas, it would be only approximately correct when applied to London or Peterborough. Second, an expansion factor is static and totally insensitive to changes in travel behaviour.

In the following section the second method, that based on work trips, trip length and average speed, will be used to estimate transportation energy. The transportation energy figures will refer only to work trips, which are the single largest component of urban travel. This method is the more accurate in terms of demonstrating the sensitivity of transportation energy consumption to changes in urban form.

3.0 APPLICATION

Quantification of land use/energy consumption relationships for the case study communities - London and Peterborough - was completed for all land use sectors and for transportation energy at a general level of analysis. As noted, the intent is to demonstrate the basic workings of the method rather than to produce accurate and detailed measurements of energy consumption.

3.1 Developing the Energy Consumption Co-efficients

Information regarding energy consumption was drawn primarily from related literature. In all sectors an attempt was made to derive co-efficients from data which was specific to Southern Ontario. Rather than theoretical energy load modelling, the data was assembled through the collection of actual energy consumption records. In all cases, energy consumption estimates were converted to Kilowatt - hours (KWH), as the commonly used energy unit with the most practical relevance to engineers, designers, utility officials and others working in energy-related fields.

Most energy studies to date have focussed on the residential sector. As a result, numerous estimates exist for energy consumption by dwelling unit type. However, relatively few are based on actual consumption data representative of Southern Ontario homes. The consumption co-efficients shown in Figure A-2 were developed through a synthesis of information from various studies and data sources, including Ontario Hydro. The residential co-efficients can be used as general estimates applicable to Southern Ontario municipalities; it is recognized that many variations will occur due to local climatic and building design variables.

FIGURE A-2

ENERGY CONSUMPTION CO-EFFICIENTS:
RESIDENTIAL SECTOR

Development Type	KWH/m^2 Living Area	Typical Dwelling Unit Area (m^2)	KWH/ Dwelling Unit (Rounded)
Detached	350(1)	130	46,000
Semi-detached/ Duplex	320(2)	115	37,000
Row	310(3)	100	31,000
Apartment	320(4)	65	21,000

Sources: (1) Estimate
(2) Estimate
(3) Estimate
(4) Ontario Hydro, Energy Use In Apartment Buildings September, 1976

The commercial sector, in terms of both land use and energy consumption, is the most complex. Numerous studies including consumption estimates for various commercial uses and commercial buildings were reviewed. The Canada Department of Energy, Mines and Resources study Patterns and Levels of Commercial and Industrial Energy Consumption: A Case Study of Metropolitan Toronto, along with recent data from Ontario Hydro, were used extensively for commercial sector information. Again, these can be used as very general indicators of consumption levels.

Consumption co-efficients per m^2 floor area were derived from the above sources for the following categories of building form (Figure A-3). Though commercial sector consumption varies with both building form and building use, refinement of co-efficients was limited to the level of building form for the purposes of this application.

FIGURE A-3

ENERGY CONSUMPTION CO-EFFICIENTS:
COMMERCIAL SECTOR

	Development Type	KWH/m^2 Floor Area
Retail:	Shopping Centre	540 (1)
	Retail Strip	640 (2)
	Food Store (in strip or shopping centre development)	1240 (3)
Service:	Office Strip	400 (4)
	Office Building	475 (5)
	Hospital	1240 (6)
	School	480 (7)
	Hotel/Motel	560 (8)
	Warehouse	400 (9)

Sources:

(1) Ontario Hydro, Energy Use In Ontario Shopping Centres, January, 1982

(2) Energy Mines and Resources, Canada, Patterns and Levels of Commercial and Industrial Energy Consumption: A Case Study of Metropolitan Toronto, 1979

(3) EMR, 1979

(4) Estimate

(5) EMR, 1979

(6) EMR, 1979

(7) EMR, 1979

(8) EMR, 1979

(9) EMR, 1979

As noted, energy consumption in the industrial sector is closely related to specific uses (and associated manufacturing processes, plant facilities, equipment, etc.). Relevant consumption data for industries across Ontario have been assembled by the Ministry

of Treasury and Economics in Consumption of Fuel and Electricity by Ontario Manufacturing Industries. This source was used directly; the co-efficients shown in Figure A-4 represent Ontario wide averages for energy consumption per industrial employee.

FIGURE A-4

ENERGY CONSUMPTION CO-EFFICIENTS: INDUSTRIAL SECTOR [1]

Food and Beverage	135000	KWH/employee
Tobacco Products	60500	KWH/employee
Rubber and Plastics	90900	KWH/employee
Leather	30700	KWH/employee
Textiles	131000	KWH/employee
Knitting Mills	46100	KWH/employee
Clothing	87000	KWH/employee
Wood	96100	KWH/employee
Furniture and Fixtures	30500	KWH/employee
Paper	550000	KWH/employee
Printing and Publishing	18500	KWH/employee
Primary Metals	444000	KWH/employee
Metal Fabricating	61900	KWH/employee
Machinery	43000	KWH/employee
Transportation Equipment	72900	KWH/employee
Electrical Products	36900	KWH/employee
Non-Mechanical Minerals	691000	KWH/employee
Petroleum and Coal	485000	KWH/employee
Chemical and Chemical Prod.	511000	KWH/employee
Misc.	31000	KWH/employee
All Manufacturing (Ontario average)	169000	KWH/employee

Source: (1) Ministry of Treasury and Economics. Consumption of Fuel and Electricity by Ontario Manufacturing Industries, 1979

The above process of assembling relevant and available data sources and carrying out the required conversions to appropriate units illustrates the simplest and most direct approach to developing a set of consumption co-efficients. In local application, the ideal approach would be to base co-efficients on local surveys of energy

consumption by building form and building type. However, in analyzing broad community land use patterns, co-efficients derived from the literature can provide enough accuracy to illustrate basic land use/energy consumption relationships.

3.2 Existing Energy Consumption: Intensity of Land Use

Figures A-5 and A-6 summarize 1981 energy consumption estimates by land use sector using the consumption co-efficients method for London and Peterborough respectively. The data sources used were those most quickly and readily available to the municipal planning departments in each case study community.

For both London and Peterborough, the residential sector consumption estimates were produced by multiplying dwelling unit data for each dwelling type by the appropriate co-efficient (see Figure A-2). It is noteworthy that the average annual energy consumption for all units in London (35,500 KWH) is lower than that for Peterborough (38,900 KWH). This reflects the greater proportion of higher density dwelling types in London, the larger City.

Quantifying commercial sector consumption was more complex. Ideally, an application at the local level would involve a detailed analysis and disaggregation of floor area data, most likely from assessment records. This would provide floorspace estimates by categories of building form or possibly by categories of building use, that could be matched to consumption co-efficients. Numerous studies have produced consumption estimates for commercial buildings and uses; these could be adopted, though local energy consumption data will often be desirable. Since this level of detail was beyond the scope and resources of the present study, a modified approach was taken.

FIGURE A-5

CITY OF LONDON: SUMMARY OF 1981 ENERGY USE
(Average annual energy consumption)

SECTOR	BASE DATA	X	ENERGY CONSUMPTION CO-EFFICIENT	=	TOTAL ENERGY CONSUMPTION (KWH x 10^7)
RESIDENTIAL					
- Detached	49700 dwellings	X	46000 KWH/dwelling	=	228.6
- Semi detached/duplex	9090 dwellings	X	37000 KWH/dwelling	=	33.6
- Row House	8110 dwellings	X	31000 KWH/dwelling	=	25.1
- Apartment	34465 dwellings	X	21000 KWH/dwelling	=	72.4
Total Residential	101365 dwellings	X	35500 KWH/dwelling	=	359.7
COMMERCIAL					
Total Retail	724840 m^2 [1]	X	700 KWH/m^2 [2]	=	50.7
Total Service	86250 employees	X	25000 KWH/employee [3]	=	215.6
Total Commercial				=	266.3

FIGURE A-5 (Cont'd)

CITY OF LONDON: SUMMARY OF 1981 ENERGY USE
(Average annual energy consumption)

SECTOR	BASE DATA	X	ENERGY CONSUMPTION CO-EFFICIENT	=	TOTAL ENERGY CONSUMPTION (KWH x 10^7)
INDUSTRIAL[4]					
Food and Beverage	4526 employees	X	135000 KWH/employee	=	61.1
Tobacco Products	- employees	X	60500 KWH/employee	=	-
Rubber and Plastics	323 employees	X	90900 KWH/employee	=	2.9
Leather	406 employees	X	30700 KWH/employee	=	1.2
Textiles	109 employees	X	131000 KWH/employee	=	1.4
Knitting Mills	- employees	X	46100 KWH/employee	=	-
Clothing	788 employees	X	8700 KWH/employee	=	0.7
Wood	356 employees	X	96100 KWH/employee	=	3.4
Furniture and Fixtures	211 employees	X	30500 KWH/employee	=	0.6
Paper	914 employees	X	555000 KWH/employee	=	50.7
Printing and Publishing	1455 employees	X	18500 KWH/employee	=	2.7
Primary Metals	703 employees	X	444000 KWH/employee	=	31.2
Metal Fabricating	3353 employees	X	61900 KWH/employee	=	20.8
Machinery	1502 employees	X	43000 KWH/employee	=	6.5
Transportation Equipment	2524 employees	X	72900 KWH/employee	=	18.4
Electrical Products	3341 employees	X	36900 KWH/employee	=	12.3
Non-Metallic Minerals	2337 employees	X	69100 KWH/employee	=	161.5
Petroleum and Coal	- employees	X	485000 KWH/employee	=	--
Chemicals	451 employees	X	511000 KWH/employee	=	23.0
Miscellaneous	316 employees	X	31000 KWH/employee	=	1.0
Total Industrial	23615 employees	X	169000 KWH/employee	=	399.4
TOTAL ALL SECTORS					1,025.4

Notes:

(1) Floorspace estimate based on City of London Retail Simulation Model, The Malone Group, 1980. A factor of 1.5 was applied to the Malone group estimates to take into account non-sales space in retail developments, and small retail stores dispersed throughout residential areas which were not included originally.

(2) 700 KWH/m^2 is a weighted average of co-efficients shown in Figure A-3. The weighting represents an approximate breakdown of: shopping centre - 25% of retail space; retail strip - 25% of retail space. 20% of strip development is assumed to be foodstore space.

(3) Assumed space per service employee = 25m^2

(4) Employment data for London based on Ministry of Municipal Affairs and Housing, 1978. Adjusted to 1981.

FIGURE A-6

CITY OF PETERBOROUGH: SUMMARY OF 1981 ENERGY CONSUMPTION
(Average annual energy consumption)

SECTOR	BASE DATA	X	ENERGY CONSUMPTION CO-EFFICIENT	=	TOTAL ENERGY CONSUMPTION ($KWH \times 10^7$)
RESIDENTIAL					
- Detached	14625 dwellings	X	46000 KWH/dwelling	=	67.3
- Semi detached/duplex	2130 dwellings	X	37000 KWH/dwelling	=	7.9
- Row House	1350 dwellings	X	31000 KWH/dwelling	=	4.2
- Apartment	5050 dwellings	X	21000 KWH/dwelling	=	10.6
Total Residential	23145 dwellings	X	38900 KWH/dwelling	=	90.0
COMMERCIAL					
Retail	174500 m^2 (1)	X	700 KWH/m^2 (3)	=	12.2
Service	13000 employees	X	25000 KWH/employee (4)	=	32.5
Total Commercial					44.7

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FIGURE A-6 (Cont'd)

CITY OF PETERBOROUGH: SUMMARY OF 1981 ENERGY CONSUMPTION
(Average annual energy consumption)

SECTOR	BASE DATA	X	ENERGY CONSUMPTION CO-EFFICIENT	=	TOTAL ENERGY CONSUMPTION (KWH x 10^7)
INDUSTRIAL(4)					
Food and Beverage	802 employees	X	135000 KWH/employee	=	10.8
Tobacco Products	- employees	X	60500 KWH/employee	=	-
Rubber and Plastics	212 employees	X	90900 KWH/employee	=	1.9
Leather	- employees	X	30700 KWH/employee	=	-
Textiles	20 employees	X	131000 KWH/employee	=	0.3
Knitting Mills	- employees	X	46100 KWH/employee	=	-
Clothing	4 employees	X	8700 KWH/employee	=	-
Wood	50 employees	X	96100 KWH/employee	=	0.5
Furniture and Fixtures	11 employees	X	30500 KWH/employee	=	-
Paper	518 employees	X	555000 KWH/employee	=	28.7
Printing and Publishing	258 employees	X	18500 KWH/employee	=	0.5
Primary Metals	- employees	X	444000 KWH/employee	=	-
Metal Fabricating	467 employees	X	61900 KWH/employee	=	2.9
Machinery	211 employees	X	43000 KWH/employee	=	0.9
Transportation Equipment	649 employees	X	72900 KWH/employee	=	4.7
Electrical Products	4345 employees	X	36900 KWH/employee	=	16.0
Non-Metallic Minerals	112 employees	X	69100 KWH/employee	=	7.7
Petroleum and Coal	- employees	X	485000 KWH/employee	=	-
Chemicals	- employees	X	511000 KWH/employee	=	-
Miscellaneous	1341 employees	X	31000 KWH/employee	=	4.2
Total Industrial	9000 employees	X	87900 KWH/employee	=	79.1
TOTAL ALL SECTORS					213.8

Notes:

(1) Dwelling unit figures based on 1981 assessment data.

(2) Floorspace estimate based on Larry Smith and Associates and discussions with Municipal Officials. Factor of 1.5 applied to estimates for core area and other strip retail areas to account for non-sales space and small stores in residential areas.

(3) 700 KWH/m^2 is a weighted average of co-efficients shown in Figure A-3. The weighting represents an approximate breakdown of: shopping centre - 20% of retail space; retail strip - 75% of retail space. 15% of strip development assumed to be foodstore space.

(4) Assumed space per service employee = $25m^2$

(5) Employment data for Peterborough based on Scott's Directory.

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Concerning the retail subsector, estimates of floorspace were derived from retail demand studies and discussions with municipal officials in both communities. From this information it was possible to disaggregate retail space into shopping centre space and retail strip space (disaggregated further into general retail and food store). As described in the footnotes to Figures A-5 and A-6, the co-efficient of 700 KWH/m^2 represents a weighted average of co-efficient from Figure A-3 according to the respective breakdowns of space into these categories. Also specified in the footnotes is the application of a factor of 1.5 to certain retail space estimates. When using data from retail demand studies it is important to note that estimates refer to sales related space only; non sales space such as storage areas must be accounted for separately. Also, small stores dispersed throughout residential areas are often ignored as insignificant for community retail demand, but nevertheless worthy of note in terms of energy consumption.

In order to construct a broad estimate of energy use in the service subsector (comprising the remainder of commercial activity) without detailed floor space data for the multitude of different services throughout each community, it was necessary to use employment data from Statistics Canada. This employment data was insufficiently disaggregated to permit a meaningful matching of data with consumption co-efficients for specific service building forms or uses.

As an alternative, a figure of 1,000 Kwh/m^2 (25,000 Kwh/employee at $25m^2$ floorspace per employee) was selected as a co-efficient representative of the average energy use throughout the entire service sector. This figure is somewhat higher than the average of service sector co-efficients shown in Figure A-3. The reason for

this is that many specific service uses, such as trade and repair shops, car washes and dry cleaners, have very high levels of energy consumption (on a per m^2 floor area basis) but have rarely been classified and analyzed in energy studies. Their effect is to raise the overall average for service consumption.

Considerable energy-related research is still required to provide the basis for accurate and reliable consumption co-efficients. Furthermore, any detailed application of the method at the local level would require careful assembly and categorization of floorspace data. However, as is demonstrated above, general energy analysis for planning purposes can be completed using readily available data. The detailed work can be developed in incremental stages over time.

Case study application of the co-efficient method in the industrial sector was aided by the fact that employment data was available which was disaggregated according to 2-digit SIC categories. It was therefore possible to estimate energy use in each industry group and for the sector as a whole. Some basic relationships concerning industrial energy consumption were revealed. For example, a very high level of energy consumption is consumed by London's non-metallic minerals industry. In Peterborough, the heavy concentration of employment in the electrical product industry (i.e. primarily General Electric) brings the average annual consumption per industrial employee to a fairly low 87,900 Kwh.

The above overview of existing energy use in the case study communities illustrates an initial application of the consumption co-efficient method. Figures derived in this manner can be compared with energy consumption data from local utilities. Subsequent and more

detailed analyses can be completed as the needs arise, and the required data becomes available.

3.3 Exisiting Energy Consumption: Distribution of Land Use

As described in Section 2.2 transportation energy use will be based on an examination of automobile work trips. The source for the data used is the Statistics Canada Annual Travel to Work Survey. This survey provides total automobile work trips, average trip length and average speed. The input data and the 1980 transportation energy estimates are set out below:

	1980 Transportation Energy	
	London	Peterborough
Daily Automobile Work Trips	210,000	42,000
Average Trip Length (km)	8.7	4.9
Total Vehicle Kilometres	1,827,000	205,800
Average Speed (km/h)	30.0	30.0
Fuel used per km at the average speed (l/km)	0.17928	0.17928
Fuel used per work day (l)	327,544	36,896
Fuel used per year (l)*	78,610,560	8,855,040
KWH per litre	9.7	9.7
Energy used per year (KWH)	76.3×10^7	8.6×10^7

* Assume 240 work days per year

In addition, comparing the 1976 and 1980 Travel to Work Survey results for London show that average trip length increased by 0.37 km, from 8.33 to 8.7, or 4.5% over 4 years. This rate of change in trip length will be used in the construction of the trends scenario, described below in Section 3.5.2.

3.4 Spatial Representation of Land Use/Energy Consumption Relationship

The representation of the land use/energy consumption relationship in spatial terms is an important part of this study which has particular relevance for municipal planning.

The following series of maps (Figures A-7 to A-14), show residential, retail, service and industrial land use for both London and Peterborough and demonstrate how energy consumption can be quantified for specified areas of a community. To assemble each map, the major concentrations of development in each sector were identified. Through the use of various planning data sources, the number of dwellings, amount of floor area, or amount of employment in each concentration was estimated. These estimates were then multipled by energy consumption co-efficients to provide general estimates of energy consumed in each concentration.

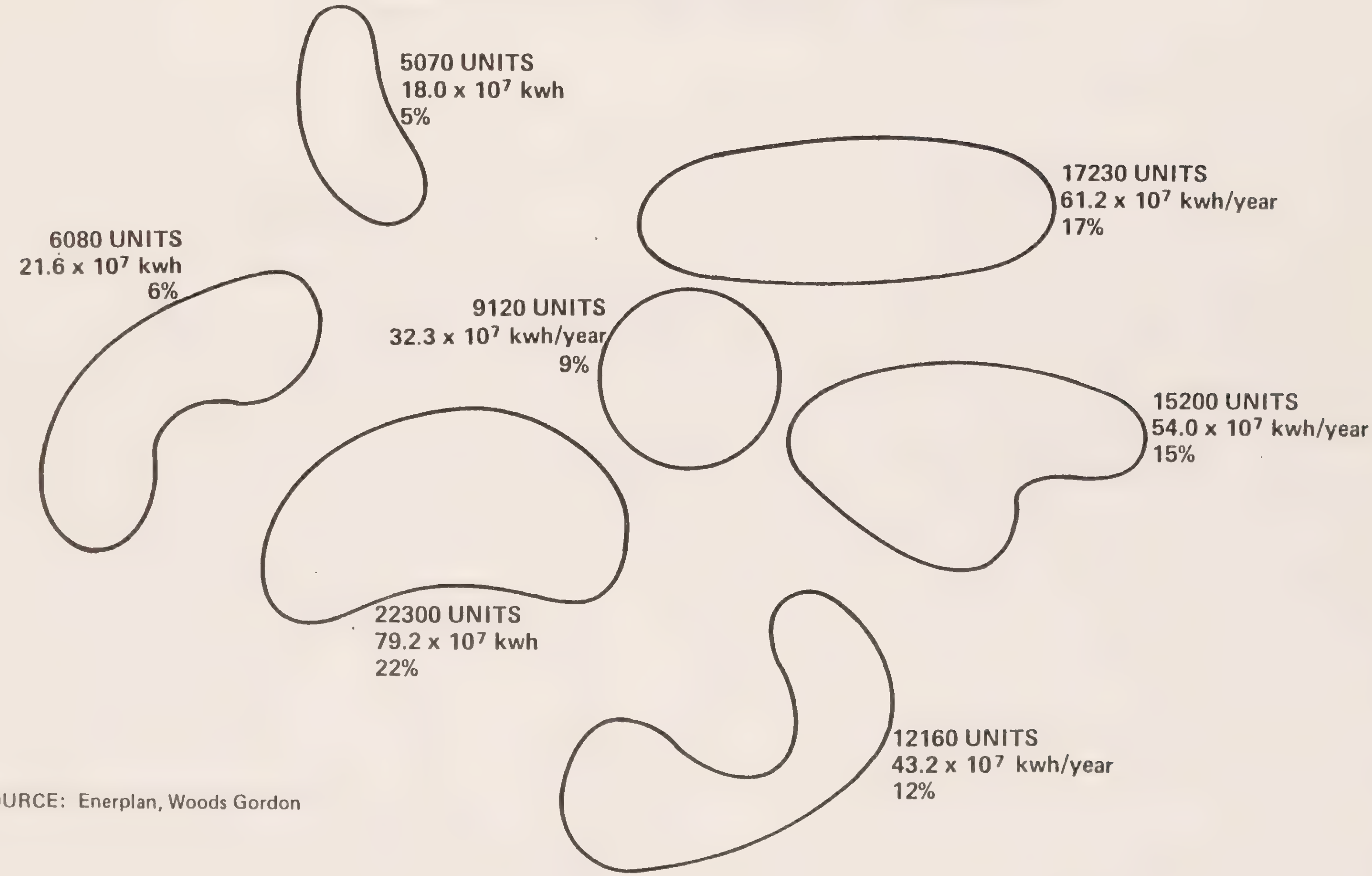
The flexibility of this procedure has obvious merits for planning purposes. Any size or shape of area can be used, provided base data and co-efficients are available. All sectors within a given area can be quantified to provide a complete picture of energy consumption. Possible applications include measurement of energy use in a secondary plan area or neighbourhood improvement area. Areas of very high consumption can be identified as locations where energy demand is sufficient to support district heating or co-generation facilities. Once again, the general workings of the method shown here can be adapted and applied to suit specific local needs.

FIGURE A-7

CITY OF LONDON

RESIDENTIAL ENERGY USE

1981 – 101365 UNITS
– TOTAL ANNUAL ENERGY CONSUMPTION = 359.7 x 10^7 kwh
– AVERAGE CONSUMPTION PER UNIT PER YEAR = 35500 kwh



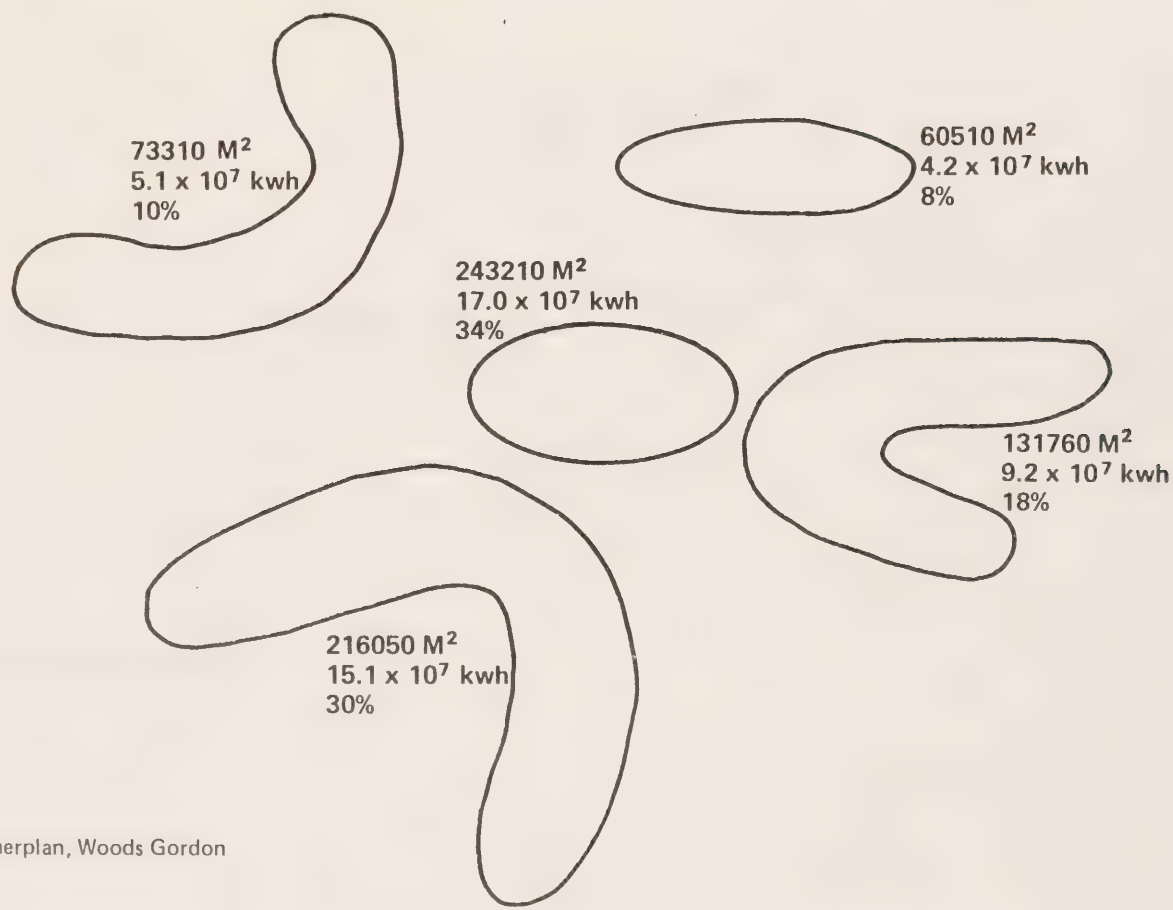
SOURCE: Enerplan, Woods Gordon

FIGURE A-8

CITY OF LONDON

RETAIL ENERGY USE

1981 – 724840 M^2 FLOOR AREA
– TOTAL ANNUAL ENERGY CONSUMPTION = 50.7×10^2 kwh
– AVERAGE ANNUAL CONSUMPTION PER M2 = 700 kwh



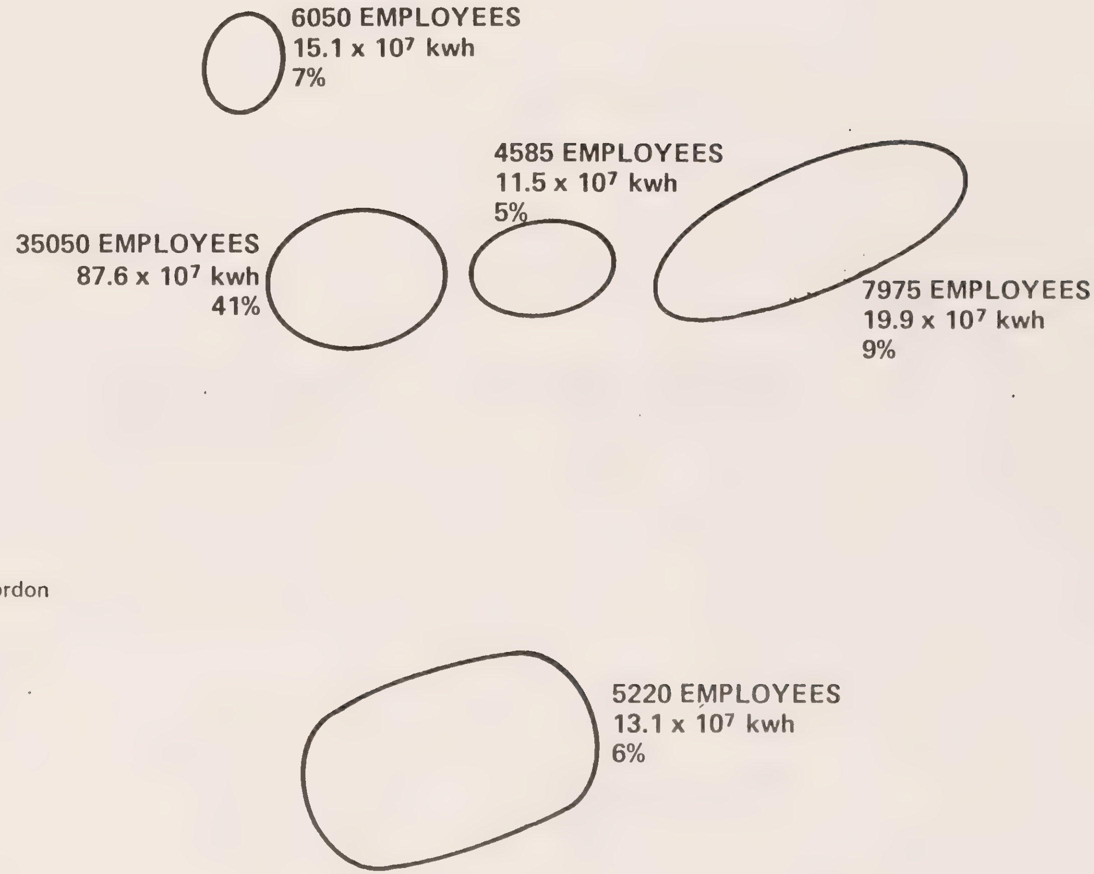
SOURCE: Enerplan, Woods Gordon

FIGURE A-9

CITY OF LONDON

SERVICE ENERGY USE

1981 – 86250 EMPLOYEES
– TOTAL ANNUAL ENERGY CONSUMPTION = 215.6 x 10^7 kwh
– AVERAGE ANNUAL ENERGY CONSUMPTION PER EMPLOYEES = 25000 kwh



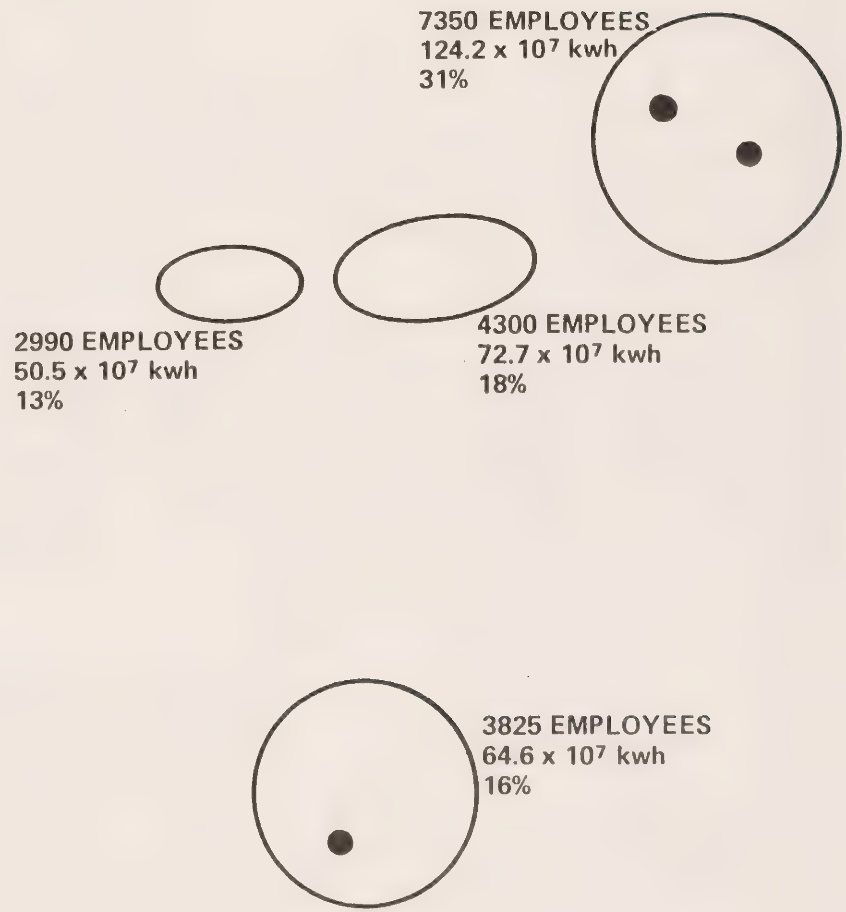
SOURCE: Enerplan, Woods Gordon

FIGURE A-10

CITY OF LONDON

INDUSTRIAL ENERGY USE

1981 – 23615 EMPLOYEES
– TOTAL ANNUAL ENERGY CONSUMPTION = 398.9×10^7 kwh
– AVERAGE ANNUAL ENERGY CONSUMPTION PER EMPLOYEE = 169000 kwh



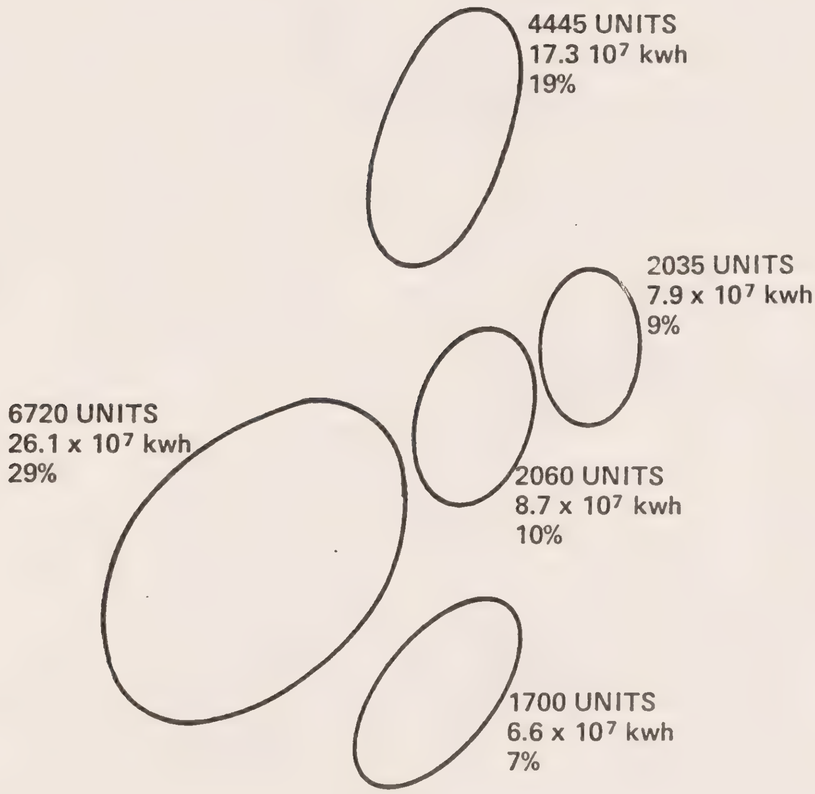
SOURCE: Enerplan, Woods Gordon

FIGURE A-11

CITY OF PETERBOROUGH

RESIDENTIAL ENERGY USE

1981
- 23145 UNITS
- TOTAL ANNUAL ENERGY CONSUMPTION = 90.0×10^7 kwh
- AVERAGE ANNUAL ENERGY CONSUMPTION PER DWELLING = 38900 kwh



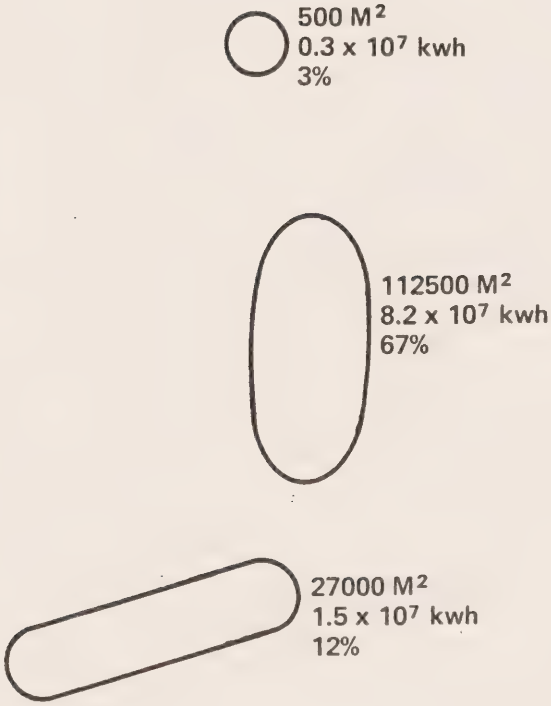
SOURCE: Enerplan, Woods Gordon

FIGURE A-12

CITY OF PETERBOROUGH

RETAIL ENERGY USE

1981 – 174500 M FLOORSPACE
– TOTAL ANNUAL ENERGY CONSUMPTION = 12.2×10^7 kwh
– AVERAGE ANNUAL ENERGY CONSUMPTION PER M^2 = 700 kwh



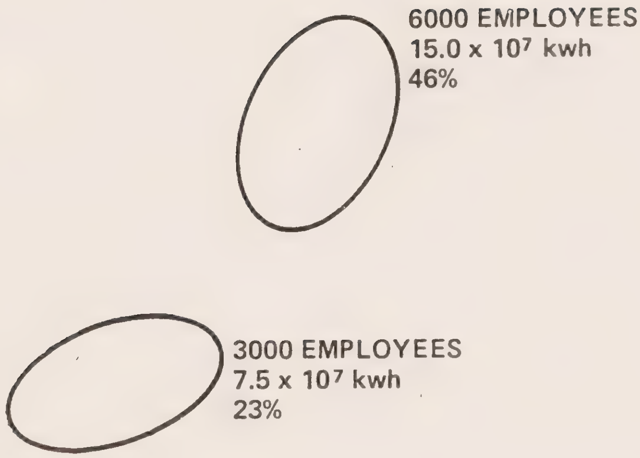
SOURCE: Enerplan, Woods Gordon

FIGURE A-13

CITY OF PETERBOROUGH

SERVICE ENERGY USE

1981 – 13000 EMPLOYEES
- TOTAL ANNUAL ENERGY CONSUMPTION = 32.5×10^7 kwh
- AVERAGE ANNUAL ENERGY CONSUMPTION PER EMPLOYEES = 25000 kwh



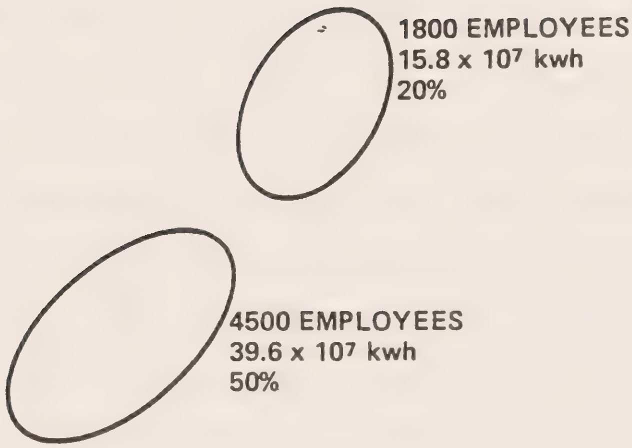
SOURCE: Enerplan, Woods Gordon

FIGURE A-14

CITY OF PETERBOROUGH

INDUSTRIAL ENERGY USE

1981 – 9000 EMPLOYEES
– TOTAL ANNUAL ENERGY CONSUMPTION = 79.1×10^7 kwh
– AVERAGE ANNUAL ENERGY CONSUMPTION PER EMPLOYEE = 87900 kwh



SOURCE: Enerplan, Woods Gordon

3.5 Scenario Development

3.5.1 Intensity of Land Use

For the purposes of this study, calculations were made for a "trends" scenario and a "low energy" scenario in each case study community. The trends scenario represents the general development characteristics that will exist in 2001 given current growth projections and current land use policies. The low energy scenario, by contrast, attempts to represent development characteristics that will exist in 2001 after a series of land use planning/energy conservation measures are implemented.

In order to ensure that any measures incorporated into a low energy scenario are practical and feasible in the local context, an evaluation matrix was designed, which assists in separating practical and feasible measures from unrealistic sources, given local circumstances. This evaluation matrix, discussed in the main report, is shown again in schematic form in Figure A-15. A feasibility analysis using this matrix was completed for both London and Peterborough. The specific procedure for using the matrix for the London and Peterborough applications will be outlined using examples.

The first step in this procedure was to develop a set of potential energy conservation measures for the vertical axis of the matrix (see Figure A-16) and a set of evaluation criteria for the horizontal axis of the matrix (see Figure A-17). Additions or deletions can be made to the list of potential measures and criteria used in the present study to suit local circumstances.

Figure A-18, from the London application, illustrates a measure - in this case "nodal concentration of development" - which scored relatively high (i.e. 21 of 40). The '+' signs indicate cases

FIGURE A-15

EVALUATION MATRIX

APPROACH	CRITERIA					TOTAL SCORE	RANKING
	DEMO-GRAPHIC	PHYSICAL	ECONOMIC	SOCIAL	LEGAL		
INTENSITY OF LAND USE							
DISTRIBUTION OF LAND USE							

SOURCE: Woods Gordon, The Starr Group, Enerplan

Figure A-16

ENERGY CONSERVATION MEASURES

Potential Measure

Intensity of Land Use

limit spatial expansion
minimize suburban sprawl
minimize highway strip development
encourage higher densities
encourage infill development
encourage core area housing
encourage comprehensive downtown revitalization
encourage cluster development
encourage nodal concentrations of development
encourage intensified use of existing shopping centres
permit development of less than full sized lots
permit residential conversions
permit conversion of use

Distribution of Land Use

integrate land use
encourage mixed use development
encourage development of multi-use centres
encourage development of multi-use buildings
encourage development of self-sufficient neighbourhoods
locate municipal activities to minimize travel
permit home occupations/ cottage industries
minimize residence to work distance
encourage development of efficient street patterns
adopt energy efficient traffic management policies
implement energy conservation oriented parking policies
encourage development of transit corridors

Potential Measure

Building Form and
Sensitivity to Climate

encourage rehabilitation
encourage south slope development, avoid north slope
locate large buildings adjacent to shadow absorption zones
implement community retrofit (e.g. retro-active solar access)
develop and encourage alternate energy supply and technology systems
encourage building shell/ heating system retrofit
encourage solar retrofit/ solar "add-ons"
encourage solar building design and engineering
encourage solar orientation
landscape for microclimate control
landscape and siting for protection from wind

Planning Tools

official plans
secondary plans
zoning
site planning guidelines/ by-laws
subdivision approval
development bonusing
density transfers
solar zoning (new and existing development)
performance criteria and standards
planned unit development

Figure A-17

CRITERIA FOR EVALUATING CONSERVATION MEASURES

Criteria

Demographic

population size
population growth rate
household size and trend
age distribution and trend

Physical

intensity of development and trend
concentration of development and trend
distribution of development and trend
  (i.e. core dominant, nodal, random)
topography/physical features
macroclimate
agricultural lands
potential development areas
existing building conditions
capacity and condition of existing
  hard services
potential for expansion of
  hard services
availability of infill sites
availability of buildings
  suitable for conversion
potential redevelopment areas
trip length between and among
  major traffic generators

Economic

employment base and trends
retail/service base and trends
industrial base and trends
housing market
housing market trends
energy prices
energy price trends
energy availability
energy availability trends
municipal finance
utility finance
construction costs
transportation demand
public transit demand

Criteria

Social

desirability/acceptance of residential development and occupancy in core area
desirability/acceptance of mixed and multi-use development
desirability/acceptance of more dense development
desirability/acceptance of more concentrated development
desirability/acceptance of less random distribution patterns
demand for soft services and trends
household energy use and trend

Legal

official plans, secondary plans
site planning guidelines
subdivision approvals
zoning by-laws

Site Specific Evaluation Criteria

microclimate
site topography
site vegetation
adjacent development density
adjacent development form
utility/servicing/transportation rights of way
site plans/by-laws

where the criterion supports the measure. The '-' signs indicates where the criteria does not support. A slash (/) indicates "not applicable". A zero (0) indicates cases where no clear relationship could be identified given current conditions, or where relationships are site specific. Figure A-18 shows that demographic conditions are favourable for nodal concentrations. A fairly large population with a steady growth rate can support higher densities at nodes; a steady reduction in household size and aging of the population generally leads to a demand for smaller dwelling units closer to mixed use nodes. London's trend toward a more concentrated and less randomly distributed land use pattern also supports nodal development. There are also some infill sites, buildings suitable for conversion, and redevelopment areas which can enable development to concentrate.

In terms of the economic criteria, it can be argued that escalating energy prices and growing public transit demands, contribute to the demand for people to live and work in central nodes along efficient transportation routes. Consideration of social criteria reveals that, given current demographic trends, the desirability and acceptance of the mixed uses, higher densities, and more concentrated and less random development associated with nodal concentration is increasing. Finally, the London Official Plan, in general, encourages a nodal development pattern. Overall, it would appear that encouraging nodal concentrations of development as a measure for promoting an energy efficient land use pattern is, in general, practical and feasible.

Conversely, the example shown in Figure A-19 for Peterborough shows how a measure can rank relatively low according to criteria of practicality and feasibility. The measure, to "encourage

FIGURE A-18

EXAMPLE OF APPLICATION OF MATRIX TO DETERMINE PRACTICAL AND FEASIBLE CONSERVATION MEASURE

CITY OF LONDON

Criteria	Sample Measure: Encourage Nodal Concentrations of Development
Demographic	
population size	+
population growth rate	+
household size trend	+
age distribution and trend	+
Physical	
intensity of development	0
concentration of development	+
distribution of development (i.e. core dominant, nodal, random)	+
topography/physical features	0
macroclimate	/
agricultural lands	/
potential development areas	0
existing building conditions	0
capacity and condition of existing hard services	0
potential for expansion of hard services	0
availability of infill sites	+
availability of buildings suitable for conversion	+
potential redevelopment areas	+
trip length between and among major generators	+
Economic	
employment base and trends	0
retail/service base and trends	+
industrial base and trends	0
housing market	0
housing market trends	0
energy prices	+
energy price trends	+
energy availability	0
energy availability trends	0
municipal finance	0
utility finance	+
construction costs	0
transportation demand	+
public transit demand	+

FIGURE A-18 (Cont'd)

Criteria	Sample Measure: Encourage Nodal Concentrations of Development
Social	
desirability/acceptance of residential development and occupancy lu core area	+
desirability/acceptance of mixed and multi-use development	+
desirability/acceptance of more dense development	0
desirability/acceptance of more concentrated development	+
desirability/acceptance of less random distribution patterns	+
demand of soft services and trends	+
household energy use and trend	0
Legal	
official plans, secondary plans	+
site planning guidelines	0
subdivision approvals	0
zoning by-laws	0
	22/41

Notes:
+ criteria supports the measure
- criteria opposes the measure
0 no clear relation between criteria and measure
/ criteria is not applicable

SOURCE: Woods Gordon, Enerplan

FIGURE A-19

EXAMPLE OF APPLICATION OF MATRIX TO DETERMINE PRACTICAL AND FEASIBLE CONSERVATION MEASURES

CITY OF PETERBOROUGH

Criteria	Sample Measure: Encourage Higher Densities
Demographic	
population size	0
population growth rate	0
household size trend	+
age distribution and trend	+
Physical	
intensity of development	-
concentration of development	-
distribution of development (i.e. core dominant, nodal, random)	0
topography/physical features	0
macroclimate	/
agricultural lands	0
potential development areas	0
existing building conditions	/
capacity and condition of existing hard services	0
potential for expansion of hard services	0
availability of infill sites	+
availability of buildings suitable for conversion	+
potential redevelopment areas	+
trip length between and among major traffic generators	+
Economic	
employment base and trends	0
retail/service base and trends	0
industrial base and trends	-
housing market	-
housing market trends	-
energy prices	+
energy price trends	+
energy availability	+
energy availability trends	+
municipal finance	0
utility finance	+
construction costs	+
transportation demand	+
public transit demand	+

FIGURE A-19 (Cont'd)

Criteria	Sample Measure: Encourage Higher Densities
Social	
desirability/acceptance of residential development and occupancy in core area	+
desirability/acceptance of mixed and multi-use development	0
desirability/acceptance of more dense development	-
desirability/acceptance of more concentrated development	-
desirability/acceptance of less random distribution patterns	0
demand of soft services and trends	+
household energy use and trend	0
Legal	
official plans, secondary plans	0
site planning guidelines	/
subdivision approvals	/
zoning by-laws	/
	15/38

Notes:
+ criteria supports the measure
- criteria opposes the measure
0 no clear relation between criteria and measure
/ criteria is not applicable

SOURCE: Woods Gordon, Enerplan

higher densities", would likely be difficult to implement as a result of an existing low density, dispersed development pattern, an industrial base which is becoming increasingly suburbanized, and a continuing local desirability for low density, dispersed development. These would tend to neutralize factors which support the measure, such as a declining household size, potential infill and redevelopment areas, rising energy prices, etc. In this case, the overall score for "encouraging higher densities" was only 9 of 37, indicating that there are important limitations on practicality and feasibility.

Following through this procedure for all of the measures listed in Figure A-16 for each community led to a set of practical and feasible measures to promote energy conservation through land use planning in London (Figure A-20) and Peterborough (Figure A-21). These are lists of the measures which received high scores in the evaluation matrix calculation.

The package of measures for each City was then used as the basis for a low energy scenario, depicting land use intensity patterns as they would exist in 2001 if the energy conservation measures were applied.

3.5.2 Distribution of Land Use

The trends scenario for transportation energy is based on the following assumptions:

- vehicle fuel efficiency is held constant to avoid mixing technological and land use pattern effects
- average trip length increases by 15% over the period 1980 to 2001. This is slightly more slowly than the 1976 - 1980 trend of 4.5% per year

FIGURE A-20

CITY OF LONDON:
PRACTICAL AND FEASIBLE ENERGY CONSERVATION MEASURES

- encourage mixed use development
- encourage development of multi-use centres
- encourage core area housing
- encourage higher densities
- encourage development of multi-use buildings
- encourage development of transit corridors
- encourage comprehensive downtown revitalization
- encourage development of self-sufficient neighbourhoods
- encourage intensified (mixed) use of existing malls
- encourage nodal concentrations of development
- encourage cluster development
- encourage infill development
- permit home occupations/cottage industries
- locate municipal activities to minimize travel
- permit residential conversions
- integrate land use
- encourage conversion of use
- encourage development of efficient street patterns

SOURCE: Woods Gordon, Enerplan

FIGURE A-21

CITY OF PETERBOROUGH: PRACTICAL AND FEASIBLE ENERGY CONSERVATION MEASURES

- encourage core area housing
- encourage infill development
- encourage nodal concentrations of development
- permit residential conversions
- adopt energy efficient traffic management policies
- encourage comprehensive downtown revitalization
- encourage development of multi-use centres
- implement energy conservation oriented parking policies
- permit home occupations/cottage industries
- encourage development of efficient street patterns
- encourage mixed use development
- encourage development of multi-use buildings
- permit conversion of use

SOURCE: Woods Gordon, Enerplan

- average speed remains constant
- number of work trips increases in proportion with the increase in the labour force in each city

Based on these assumptions, total transportation energy will increase for two reasons, the increase in total labour force and the increase in average trip length. The numeric results of this trends scenario are given below (Section 3.6).

For the purposes of the low energy scenario, we would prefer to use a traffic flow simulation model to generate a revised average trip length based on the new, low energy, land use distribution. Such a modelling exercise is beyond the scope of this study, although it would be a useful extension to this methodology.

In place of a detailed modelling approach, we have chosen to examine the sensitivity of transportation energy use to changes in average trip length by using a lower percent change in trip length than is indicated by the historic trend.

For London the trends scenario 2001 trip length of 10.0 km is 15% greater than the 1980 trip length. For the low energy scenario this increase was reduced by 2/3 to be a 5% increase. This gives a 2001 figure of 9.14 km. Similarly, for Peterborough, the 15% increase was reduced to 5%. This lowers the average 2001 trip length from 5.64 km in the trends scenario to 5.15 km in the low energy scenario.

The numeric results of the low energy scenario are given below (Section 3.6).

3.6 Quantification of Scenarios

Figure A-22 shows the results of quantification of the trends scenario and a low energy scenario for London. Figure A-23 presents a similar listing for Peterborough. Figure A-24 shows the results of the transportation energy analysis. Figure A-25 provides an overall summary of the results, and Figure A-26 shows the summary results in dollar terms of 1982 price levels.

Quantification of the trend scenario in both cases was based on application of the consumption co-efficients used in determining 1981 energy use to current projections for housing units, floor space and employment in 2001. A detailed construction of low energy scenarios showing, for example, the exact sizes and locations of mixed use developments, infill developments, core area housing developments, transit corridors, higher densities, etc., was beyond the scope of this study. However, it is possible to illustrate the magnitude of energy savings which could realistically occur as a result of energy conservation initiatives. From a broad planning perspective, many of these initiatives result in significant alterations in the distribution of dwelling unit types, commercial building types and possibly industrial uses. These alterations result in reduced community energy consumption which is attributable to land use measures only (i.e. no technological improvements in the energy efficiency of buildings or vehicles are assumed).

Calculations for the residential sector provide the best illustrations of scenario quantification. The implementation of measures such as infill development, core area housing, conversions, higher densities, etc., results in a higher proportion of medium and high density dwellings than in the trends scenario.

FIGURE A-22

CITY OF LONDON: QUANTIFICATION OF SCENARIOS
(Energy figures represent annual consumption)

RESIDENTIAL SECTOR

	Trends Scenario: 2001			Low Energy Scenario: 2001		
	Dwelling Units	KWH/ Dwelling	Energy Consumption (KWH x 10^7)	Dwelling Units	KWH/ Dwelling	Energy Consumption (KWH x 10^7)
Detached	62790	46000	288.8	56800	46000	261.3
Semi-detached/duplex	11400	37000	42.2	12790	37000	47.3
Row House	11470	31000	35.6	14810	31000	45.9
Apartment	42705	21000	91.8	44965	21000	94.4
Total Residential	129365	35400	458.4	129365	34600	448.9

COMMERCIAL SECTOR

	Trends Scenario: 2001			Low Energy Scenario: 2001		
	m^2 floor area / Employment	KWH/m^2 / KWH/employee	Energy Consumption (KWH x 10^7)	m^2 floor area / Employment	KWH/m^2 / KWH/employee	Energy Consumption (KWH x 10^7)
Retail	857740m^2	(1)	57.9	857740m^2	(1)	57.9
Service	137700 employees	25000 KWH/ employees	344.3	137700 employees	(2)	331.4
Total Commercial			402.2			389.3

FIGURE A-22 (Cont'd)

CITY OF LONDON: QUANTIFICATION OF SCENARIOS
(Energy figures represent annual consumption)

INDUSTRIAL SECTOR

	Trends Scenario: 2001			Low Energy Scenario: 2001		
	Employment	KWH/ Employee	Energy Consumption (KWH x 10^7)	Employment	KWH/ Employee	Energy Consumption (KWH x 10^7)
Food and Beverage	5806	135000	78.4	5506	135000	74.3
Tobacco Products	-	605000	-	-	60500	-
Rubber and Plastics	523	90900	4.8	523	90900	4.8
Leather	406	30700	1.2	406	30700	1.2
Textiles	109	131000	1.4	109	131000	1.4
Knitting Mills	-	46100	-	-	46100	-
Clothing	788	8700	0.7	788	8700	0.7
Wood	706	96100	6.8	706	96100	6.8
Furniture and Fixtures	511	30500	1.6	711	30500	2.2
Paper	914	555000	50.7	914	555000	50.7
Printing and Publishing	1695	18500	3.1	1895	18500	3.5
Primary Metals	803	444000	35.7	753	444000	33.4
Metal Fabricating	6153	61900	38.1	6453	51900	39.9
Machinery	1502	43000	6.5	1502	43000	6.5
Transportation Equip.	6424	72900	46.8	6424	72900	46.8
Electrical Products	3791	36900	14.0	3841	36900	14.2
Non-Metallic Minerals	3587	691000	247.9	3087	619000	213.3
Petroleum and Coal	-	485000	-	-	485000	-
Chemicals	451	511000	23.0	451	511000	23.0
Miscellaneous	1205	31000	3.7	1205	31000	3.7
Total Industrial	35374	159000	563.0	35374	148000	525.3
TOTAL ALL SECTORS			1,425.0			1,364.6

Notes:

(1) Two co-efficients were applied: 700 KWH/m^2 for the 724840 m^2 space already existing (see Figure A-5); 540 KWH/m^2 for the 132900 m^2 space anticipated 1981 to 2001 (primarily shopping centre development).

(2) Two co-efficients were applied: 25000 KWH/employee for the 86250 existing service employees (see Figure A-5); 22500 KWH/employee for the 51450 employees anticipated 1981 to 2001.

Figure A-22 shows a residential dwelling unit distribution which is based on the "low scenario" projection in Land Development Strategy for London to 2010, produced by the City Planning Department. The modified distribution in the low energy scenario results in an annual consumption of 448.9×10^7 Kwh, which represents an annual savings of approximately 2% or $3 million at 1982 prices. For Peterborough (Figure A-23), the trend scenario for residential development was based on Official Plan assumptions for unit distribution and projections based on Census data. The low energy distribution of dwelling unit types results in annual savings of approximately 4.2×10^7 Kwh, or $1.5 million at 1982 prices.

Comparison of scenarios for the commercial sector, in this application, required different approaches for the retail and service subsectors.

Projections of future retail development for the trend scenarios were constructed using the retail demand studies and discussions with local officials. In both London and Peterborough, plans for retail space are relatively fixed; specific retail developments are already planned which should provide sufficient space for several years - perhaps to 2001. An examination of planned retail developments revealed that both cities incorporated principles of strengthening the core area, encouraging nodal concentrations of development, and avoiding highway strip development into current planning. This meant there was no clear need for changing current retail development plans for a low energy scenario.

Regarding service-commercial development, the absence of a detailed breakdown of service buildings and/or uses precluded the

specific construction of low energy scenario based on a modified distribution of development types. In order to provide some indication of energy savings which might occur, the consumption co-efficient representing energy use per service employee was reduced by 10% for new employment generated to 2001. This 10% reduction in average energy consumption is considered attainable through clustering service uses at nodes, developing multi-use buildings, increasing densities, etc. This magnitude of change would result in approximate annual savings of 12.9×10^7 Kwh ($4.5 million) in London and 0.5×10^7 Kwh ($0.2 million) in Peterborough. These figures can be considered only as hypothetical estimates; to construct an accurate picture of potential savings in a low energy scenario, suitably disaggregated floor area data and projection for service sector growth by each sub-category would be required. Given this data, the basic procedure of multiplying floor space esimates for sub-categories by the appropriate co-efficients would result in much more accurate estimates for service sector energy consumption.

The analysis which was carried out for London illustrates the kinds of findings which can be derived through scenario quantification in the industrial sector. Employment forecasts by 2-digit SIC categories for the trend scenario are based on a Ministry of Municipal Affairs and Housing report entitled London Area Industrial - Commercial Study, Phase Two Report, 1980, which identified various growth industries and estimated additional employment requirements to 2001. These forecasts predict a continued high proportion of employment in high energy use industries such as non-metallic minerals and other "heavy" manufacturing activities. If

FIGURE A-23

CITY OF PETERBOROUGH: QUANTIFICATION OF SCENARIOS
(Energy figures represent annual consumption)

RESIDENTIAL SECTOR

	Trends Scenario: 2001			Low Energy Scenario: 2001		
	Dwelling Units	KWH/ Dwelling	Annual Energy Consumption (KWH x 10^7)	Dwelling Units	KWH/ Dwelling	Annual Energy Consumption (KWH x 10^7)
Detached	18850	46000	86.7	16100	46000	741.1
Semi-detached/duplex	2610	37000	9.7	3300	37000	12.2
Row House	1740	31000	5.4	3400	31000	10.5
Apartment	5800	21000	12.2	6200	21000	13.0
Total Residential	29000	39300	114.0	24000	37900	109.8

COMMERCIAL SECTOR

	Trends Scenario: 2001			Low Energy Scenario: 2001		
	m^2 floor area / Employment	KWH/m^2 / KWH/employee	Energy Consumption (KWH x 10^7)	m^2 floor area / Employment	KWH/m^2 / KWH/employee	Energy Consumption (KWH x 10^7)
Retail	211000m^2	(1)	14.5	211000m^2	(1)	14.5
Service	15200 employees	25000 KWH/ employee	38.0	15200 employees	(2)	37.5
Total Commercial			52.5			52.0

growth is slower than forecasted in these high energy consuming industries, and more rapid growth occurs in those industries consuming much less energy, results in annual savings of approximately 37.7×10^7 Kwh ($13.2 million). Once again, no technological improvements in energy efficiency are assumed.

Obviously there are many important factors beyond the control of municipal planning which determine patterns and rates of industrial growth. However, even the simple exercise outlined above indicates that planners should be aware of the energy use characteristics of various industries. Any land use policies or by-laws which influence or control the kinds of industries which locate in a municipality will also have significant impacts on community energy consumption.

In Peterborough, where a very high proportion of industrial employment is concentrated in the electrical products industry, the situation is quite different. Though a more detailed analysis involving projection for growth by specific industry was not completed for Peterborough (projections for a trend scenario similar to those applied in London were not available), it is evident that any realistic alterations in the distribution of employment for a low energy scenario would produce less dramatic reductions in energy consumption. This is because the electrical products industry already consumes relatively low levels of energy per employee, and the heavy consumers do not comprise a large portion of the local industrial base.

From a community energy use perspective, significant alterations in the distribution of industrial growth may not be desirable. As an example of the kind of reductions which might occur if growth in the high energy users was very slow, the consumption

FIGURE A-24

QUANTIFICATION OF SCENARIOS

DISTRIBUTION OF LAND USE

	Transportation Energy 2001		
	Trends Scenario	Low Energy Scenario	% Change[1]
London			
Daily Auto Work Trips	285,000	285,000	
Average Trip Length (km)	10.0	9.14	-8.6%
Total Vehicle Kilometres	2,850,000	2,604,900	
Average Speed (km/h)	30.0	30.0	
Fuel Used at Average Speed (l/km)	0.17928	0.17928	
Fuel Used per Day (l)	510,948	467,006	
Fuel Used per Year (l)[2]	122,627,520	112,081,968	
KWH per litre	9.7	9.7	
Energy Used per Year (KWH)	118.9×10^7	108.7×10^7	-8.6%
Peterborough			
Daily Auto Work Trips	48,450	48,450	
Average Trip Length (km)	5.64	5.15	-8.7%
Total Vehicle Kilometres	273,258	249,518	
Average Speed (km/h)	30.0	30.0	
Fuel Used at Average Speed (l/km)	0.17928	0.17928	
Fuel Used per Day (l)	48,989	44,733	
Fuel Used per Year (l)[2]	11,757,360	10,735,920	
KWH per litre	9.7	9.7	
Energy Used per Year (KWH)	11.4×10^7	10.4×10^7	-8.8%

Notes:

(1) Differences between the percent change figures are due to rounding of intermediate results.

(2) Based on 240 work days per year.

Source: Woods Gordon

co-efficient representing an average for all industries was reduced by 5% (to 83,500 Kwh) and applied in the low energy scenario. The resulting annual savings would be in the order of 5.3×10^7 Kwh ($2 million).

Overall, for the industrial sector, as well as for the other sectors, more detailed community specific and area specific analyses are possible using the same procedures applied above.

The transportation sector results are shown in Figure A-24. These results are based on the assumptions outlined in Section 3.5.2. Because total automobile work trips and average speed are held constant, the reduction in energy used in the low energy scenario depends only on the change in trip length. Changes in urban form will affect number of automobile work trips (as modal split and vehicle occupancy change) and will also affect average speed (as congestion levels change). It is expected that auto work trips would decline as a proportion of total trips and that congestion levels would increase (due to overall higher densities, nodal development and corridor development). The effects of these changes can easily be examined with this methodology. Appropriate percent changes can be made to the work trip and average speed inputs.

Summary results for both land use intensity and land use distribution are shown in Figures A-25 and A-26. Transportation energy will not equal 25% of the total energy as only passenger work trips were examined. Figure A-26 is of particular interest becuase it translates the energy estimates into dollar figures.

FIGURE A-25

SUMMARY OF
DIRECT ENERGY SAVINGS

ENERGY EXPRESSED AS KWH X 10^7 PER YEAR

LONDON	2001	
	TRENDS SCENARIO	CONSERVATION SCENARIO
RESIDENTIAL	458.4	448.9
RETAIL	57.9	57.9
SERVICE	344.3	331.4
INDUSTRIAL	564.4	526.4
TRANSPORTATION (Work Trips Only)	118.9	108.7
TOTAL	1,543.9	1,473.3

PETERBOROUGH	2001	
	TRENDS SCENARIO	CONSERVATION SCENARIO
RESIDENTIAL	114.0	109.8
RETAIL	14.5	14.5
SERVICE	38.0	37.5
INDUSTRIAL	105.5	100.2
TRANSPORTATION (Work Trips Only)	11.4	10.4
TOTAL	283.4	272.4

SOURCE: Woods Gordon, Enerplan

FIGURE A-26

SUMMARY OF
DIRECT ENERGY SAVINGS

ENERGY EXPRESSED AS MILLIONS
OF DOLLARS PER YEAR IN 1982 PRICES(1)

LONDON	2001	
	TRENDS SCENARIO	CONSERVATION SCENARIO
RESIDENTIAL	$160.4	$157.1
RETAIL	20.3	20.3
SERVICE	120.5	116.0
INDUSTRIAL	197.5	184.2
TRANSPORTATION (Work Trips Only)	47.6	43.5
TOTAL	$546.3	$521.1

PETERBOROUGH	2001	
	TRENDS SCENARIO	CONSERVATION SCENARIO
RESIDENTIAL	$39.9	$38.4
RETAIL	5.1	5.1
SERVICE	13.3	13.1
INDUSTRIAL	36.9	35.1
TRANSPORTATION (Work Trips Only)	4.6	4.2
TOTAL	$99.8	$95.9

(1) For Land Use an average cost of 3.5 cents per KWH was used. This is based on an average cost of all energy sources utilized in land uses. It includes consideration of lower rates for bulk users of electricity and natural gase. For Transportation an average cost of 4.0 cents per KWH was used. This is based on gasoline costing 39 cents per litre.

SOURCE: Woods Gordon, Enerplan

In total the low energy scenario saves 25.1 million dollars per year in London by 2001. This is a 4.6% saving. In Peterborough 3.9 million dollars is saved annually (3.9% of the total). These figures are impressive when it is realized that they are annual figures and that similar savings could be realized in most Ontario municipalities.

4.0 Concluding Remarks

This Appendix has detailed the procedures which were used for quantifying land use/energy consumption relationships in the Community Land Use Patterns and Energy Conservation Study. As noted throughout the Appendix, the intention has been to outline and illustrate the workings of the method rather than to arrive at exact figures for existing or forecasted energy consumption in London and Peterborough.

The Appendix is most valuable if used in conjunction with the main report to assist in understanding land use/energy consumption relationships through local level applications. It is at the local municipal level where the procedures discussed have the greatest potential for successful application.

CONVERSION FACTORS

ENERGY UNIT CONVERSIONS

1 BTU	=	1,055 J
	=	$29{,}31 \times 10^{-5}$ KWH
1 KWH	=	3,412 Btu
	=	$3{,}60 \times 10^{6}$ J
1 Joule	=	94.78×10^{-5} Btu
	=	27.78×10^{-8} KWH

ENERGY CONTENT OF FUELS

Crude Petroleum	=	5,145 MJ/kg (138,100 Btu/gal)
Fuel Oils		
Residual	=	41.73 MJ/L (149,700 Btu/gal)
Distillate (diesel fuel)	=	38.66 MJ/L (138,700 Btu/gal)
Automotive Gasoline	=	34.84 MJ/L (125,000 Btu/gal)
	=	9.7 KWH/L
Coal		
Anthracite	=	29.7 MJ/kg (25.4×10^{6} Btu/short ton)
Bituminous	=	30.6 MJ/kg (26.2×10^{6} Btu/short ton)
Lignite	=	14.5 MJ/kg (12.4×10^{6} Btu/short ton)
Bituminous and Lignite		
Production average	=	27.5 MJ/kg (23.5×10^{6} Btu/short ton)
Consumption average	=	26.7 MJ/kg (22.8×10^{6} Btu/short ton)
Natural gas		
Wet	=	40.79 MJ/kg (1,095 Btu/ft^3)
Dry	=	38.04 MJ/kg (1,021 Btu/ft^3)
Liquid	=	3,569 MJ/kg (95,800 Btu/gal)
AVGAS	=	34.56 MJ/L (124,000 Btu/gal)

CONVERSION FACTORS

ENERGY CONTENT OF FUELS

Jet Fuel (naphtha)	=	35.54 MJ/L (127,500 Btu/gal)
Jet Fuel (kerosene)	=	37.63 MJ/L (135,000 Btu/gal)
Asphalt and Road Oil	=	44.04 MJ/L (158,000 Btu/gal)

Abbreviations used:

L - Litre
MJ - Megajoule
Btu - British Thermal Unit
KWH - Kilowatt Hour